Exploring Castor Seed oil for Development of Small and Medium Scale Industries - A Review

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ABSTRACT

Castor oil has the potential to replace petroleum-based products for development of small and medium scale industries. It is biodegradable, sustainable and renewable. The oil has approximately 90 % ricinoleic acid (12-hydroxyoctadec-9-enoic acid), a fatty acid with three functional groups. These three functional groups make castor oil unique with versatile applications in chemical industries. The three functional groups: carboxylic, double bond and hydroxyl, undergo transformations resulting in products that intermediates or raw materials for so many industrial products. These products are conventional being produced from non-degradable petroleum base products. Most notable areas of industrial applications of castor oil are in medicine, biofuels, cosmetics, polymers, solvents, dyeing and printing, pesticides and insecticides, fungicides and many others. The oil is non-edible and can be extracted from castor bean seed by cold pressing, solvent extraction and mechanical pressing. The functionalities of the oil enable it to undergo esterification, hydrolysis, hydrogenation, halogenation, pyrolysis, amidation, dehydration, sulphation and epoxidation reactions. Exploration and exploitation of castor oil will provide industrial raw materials for small and medium scale industries in Nigeria especially.

Keywords: Castor oil, development, medium scale industries, small scale industries

The Castor Plant

Castor seed plant (*Ricinus Communis* L.) belongs to the family of *Euphorbiaceae* and grows in different regions of the world. The plant is believed to have originated from the Abyssinia region, Eastern Africa [1]. It is also indigenous to the south-eastern Mediterranean Basin and India, while it is widespread throughout tropical regions. According to Mubofu [2], castor plant (*Ricinus Communis*) is perennial and grow between 10 and 12 m in tropical climates, while in temperate climates it is an annual plant with common heights of 1–3 m [2]. Castor seed is the castor bean, which, despite its name, is not a true bean, contains between 40% and 60% oil that is

rich in triglycerides, mainly ricinolein [1, 2]. The oil content varies according the climatic conditions and method of extraction. Its physical and chemical properties such as saponification, iodine value and acid value also vary according the climatic conditions and method of extraction [2]. It is a drought-resistant tropical plant that thrives in hot and sunny climates [3]. The plant can be considered a low-cost source of castor oil in world markets.

Castor Oil

The castor bean is completely usable. Its main product is oil which has numerous industrial applications and the by product is bean cake which is used for organic fertilizer [3]. Castor oil is a translucent liquid with a yellow tint well known for its active ingredient in a wide variety of household items, from cleaning products to paints [4]. The oil is rich in ricinoleic acid which constitutes about 90% of the oil with three functional groups: hydroxyl, double bond and carboxylic [2]. The oil is unique because of its high ricinoleic acid (12-hydroxyoctadec-9-enoic acid) content and the hydroxyl functionality of the ricinoleic acid gives the oil good oxidation stability, shelf life, and a point of reaction for various chemical reactions [1]. The three functionalities are crucial towards the versatility of the oil for the production of variety of castor oil based products [2]. Castor oil has numerous applications in transportation, cosmetics, pharmaceutical and manufacturing industries. It is used in the manufacture of adhesives, brake fluids, caulks, dyes, electrical liquid dielectrics, humectants, hydraulic fluids, inks, lacquers, leather treatments, lubricating greases, machining oils, paints, pigments, polyurethane, adhesives, refrigeration lubricants, sealants, textiles, washing powders, and waxes. Castor oil can be purified by degumming by centrifugal force, alkali treatment to remove excess free fatty acids, deodorization by steam stripping, and decolourization using various ion exchange media, such as clays [5].

The leading castor oil producers are Brazil, China and India with India accounts for 90 % exporter [6]. The major consumers of castor oil are US, Europe and China. 4 % linoleic acid, 3 % oleic acid, 1 % steric acid, and about 1 % linolenic acid [5]. Annual consumption of castor oil is measured by hundreds of thousands of gallons, where that of either cotton-seed oil or linseed oil amounts to tens of millions [7].

Products derivable from Castor seed oil

Castor oil is non-edible and can be extracted from castor bean seed by cold pressing, solvent extraction and mechanical pressing. The end use of the oil depends on the method of extraction [2]. Castor oil is a pale yellow liquid extracted from castor seeds (*Ricinus Communis*). Castor oil has long been used commercially as a highly renewable resource in many chemical industries [6]. It is anti-inflammatory and antioxidant that has been used for centuries for its therapeutic and medicinal benefits. Most of the benefits of castor oil are believed to derive from its high concentration of unsaturated fatty acids. Castor oil is considered to be of importance to the global specialty chemical industry because it is the only commercial source of a hydroxylated fatty acid [6]. Mobufo [2] claimed that the oil now has estimated over 700 industrial uses and the uses keep on increasing.

With a wide diversity of commercial applications castor has considerably more uses directly related to the unique hydroxyl fatty acid structure [8]. Although castor oil has a strong and rather unpleasant taste [6]. According to Baker and Grant [5], castor oil may be dehydrated, ethoxylated, hydrogenated, oxidized, or sulphated. Each of these processes yield different chemical and physical properties that makes the oil has wide applications. Patel *et al.*, [6], reported that the presence of the hydroxyl group in ricinoleic acid and its derivatives provides a functional group location for performing a variety of chemical reactions including halogenation, dehydration, alkoxylation, esterification, and sulfation. As a result, this unique functionality allows the castor oil to be used in industrial applications such as paints, coatings, inks, and lubricants.

Castor Oil is the raw material for the production of a number of chemicals, notably sebacic acid, undecylenic acid, and nylon-11 [5]. Sebacic acid is the major ingredient in the production of synthetic resins and fibres uses castor oil as its chief raw material. The production of lithium grease consumes a significant amount of castor oil.

Castor oil is also widely used as a bio-based polyol in the polyurethane industry [9]. According to Patel *et al* [6], the hydroxyl functionality of ricin oleic acid makes the castor oil a natural polyol providing oxidative stability to the oil, and a relatively high shelf life compared to other oils by preventing peroxide formation. The presence of hydroxyl group in ricin oleic acid of

castor oil provides additional functionality for the preparation of polyesters or polyester-anhydrides [6].

The three functional groups in ricinoleic acid in castor undergo transformations to yield a variety of products that are useful in chemical industries. The carboxylic group undergoes esterification and amidation, the double bond undergoes hydrogenation and the hydroxyl group undergoes carbonylation, epoxidation, acetylation and hydration [2].

Products derivable from Castor seed oil include:

(i) Cosmetics

The highest concentrations of castor oil in cosmetic products are found in lipsticks, which in some cases may be over 80% castor oil [5]. Castor oil is rich in ricin oleic acid, a monounsaturated fatty acid which act as humectants and can be used to moisturize the skin. Humectants retain moisture by preventing water loss through the outer layer of the skin. It is often used in cosmetics to promote hydration and often added to products like lotions, makeup and cleansers. Castor oil and ricin oleic acid are thought to increase absorption in the skin and are sometimes used in the treatment of various skin conditions, including dermatosis, psoriasis, and acne [4]. Kubala [10] reported that castor oil is thick, and so it is frequently mixed with other skin-friendly oils like almond, olive and coconut oil to make an ultra-hydrating moisturizer. Castor oil can be used in many popular moisturizing products like preservatives, perfumes and dyes found in stores contain potentially harmful ingredients, which could irritate the skin and harm overall health. It combines well with styrene and diisocyanates for film forming varnish [8]. Sulphation of castor oil produces sulphuric acid esters known as Turkey-red oil used in cosmetics industries for producing detergents [2]. Mufobu [2] also reported that due to insoluble hydrogenated product of the oil, it is used in hair dressing.

(ii) Medicine

Castor oil is a known purgative, cure of rheumatism, lumbago, skin affections, cramps, colds, and a host of other illnesses [7]. It was used to regulate digestive health in olden days [11]. Both castor oil and ricin oleic acid have demonstrated anti-inflammatory properties which make them useful for treating irritated skin [4]. Castor oil is commonly used as a preparation means for radiological and colonoscopy examinations [12]. According to Patel *et al* [6], in modern-day

medicine, castor oil is also used as a drug delivery vehicle. In the small intestine, castor oil is broken down into ricin oleic acid which speeds up the process of digestion [4]. It is classified as a stimulant laxative, meaning that it increases the movement of the muscles that push material through the intestines, helping clear the bowels [13]. Its value as a medicine has declined in public esteem [7] due to toxic enzyme ricin which can cause dehydration and nutrient loss when consumed [4]. However, the heating process that castor oil undergoes during extraction deactivates the toxic enzyme thereby allowing the oil to be used safely [13]. It is reported by Tunaru *et al* [13] that, castor oil is one of the oldest drugs when given orally. It has a laxative effect and induces labour in pregnant females. For over a thousand years it has being used by medical professionals to induce birth. Therefore, women at all stages of pregnancy should avoid consuming castor oil as it may lead to loss of pregnancy. Castor oil is used as lubricant component of coatings for vitamin and mineral tablets [8].

(iii) Oleochemicals and Polymers

Because of hydroxyl functionality in its structure, the oil is suitable for use to make polyurethane millable, polyurethane elastomers, adhesives and coatings [14]. Polyurethane casting resins, fluid for automobiles, trucks and machinery are the other applications of castor oil [8]. According to Nautiyal [8], hydrolysis of hydrogenated castor oil yield a wax solid, brittle, high melting point 12-hydroxyl stearic acid (12-HAS) which is used in the production of acrylic polymers, as an internal lubricant in the molding of plastics, aviator and synthetic rubbers. Sebacic acid a hydrolytic product of castor oil is used as a monomer when reacted with hexamethylenediamine nylon 6-10 is produced. Undecylenic acid from pyrolysis of the castor oil is used for production of nylon 11[2].

(iv) Fuel

Castor oil, like currently less expensive vegetable oils, can be used as feedstock in the production of biodiesel. Castor is considered to be one of the most promising nonedible oil crops for biofuel production. Patel *et* al., [6], reported that methyl esters of castor oil can be used as a biodiesel. The resulting fuel is superior for cold winters. In Brazil, government policies promoted castor as a biodiesel feedstock in an attempt to bring social benefits to small farmers in the semiarid region of the country [6]. However, due to its higher demand by chemical industries, the products are

sold to industries for higher profit. Daugherty [7] reported that British Indians in America used castor oil for lamp fuel for illumination. It was used extensively in Australia and America for lubricating machines. Hydrogenated castor oil is insoluble in water and other organic solvent hence good for lubricating oil [2]. It is reported by Nautiyal [8], that 12-HSA obtained from castor oil is used in the manufacturing of lithium and calcium grease. Linoleic acid, a product of dehydration of ricinoleic acid of castor oil is used for production of lubricants [2]. Ester of sebacic acid, dioctysebacate is used for production of jet lubricant and air cool combustion motors likewise undecylenic acid from pyrolysis of the oil and Turkey red oil from sulphation are good lubricant [2].

(v) Dyeing and Printing Industries

The demand for castor oil by dyeing and printing industries has increased tremendously due to supplantment of aniline dyes. Daugherty [7] reported that, the popular red, formerly known as Adrianople red, but now commonly as known Turkey red oil, famous for the permanency, intensity, and beauty of its colour, owes its quality of exceptional fastness to castor oil. The Turkey-red oil is prepared from the mixture of castor oil and a small quantity of concentrated sulphuric acid [2]. A solution of common salt is used to wash off the acid and soda or ammonia is added to remove fatty acids of the oil by saponification. The product is known as suppurated castor oil, sulfuricinate, soluble oil, etc., but from its use upon cotton materials it is generally known as alizarine assistant or Turkey-red oil [7]. 12-HSA a derivative of castor is used as theological modifier in inks [8]. Linoleic acid from dehydration and Turkey red oil from sulphation of ricinoleic acid of castor oil is used for production of inks and dyes [2].

(vi) Pesticides

The use of pesticides is still the main strategy employed in the control and prevention of agricultural pests, aiming at greater productivity allied to lower costs [3]. Castor-derived products are currently used for protecting agricultural crops and seeds from devastating damages of pests and diseases. Treating pests with castor oil is a natural, non-toxic way to repel these unwanted digging animals in the garden without hurting them or causing poisonous chemicals to build up in the garden and ground water [10]. Its primary pesticidal use is as an insecticide, but it is also used as a repellent for moles, gophers, armadillos, and other burrowing

vertebrate pests [5]. It is safe, non-toxic herbicides, sustainable gardening practices and natural pesticides. It repels the pests by its bitter taste and unpleasant smell. It neither kills the animals nor pollutes the soil, hence it is environmentally safe and eco-friendly. According to Grant [9], the pesticide is prepared by mixing two part of castor oil with one part of dish soap until the mixture is foamy. Two table spoon full of the solution is mixed with 3 to 4 litres of water and apply evenly on the affected area weekly for effective pest control.

Haghtalab *et al* [16] reported that in ancient times oils obtained from locally available plants were used for stored grain protection against insects attack. They further claimed that the action of vegetable oils could be due to anoxia or interference on normal respiration resulting in suffocation. Extracts (1–10%) of leaf or seed in water or chemical solvents, and crude oil (3–5%) extracted from seed were found effective as sprays against foliage insect pests [17]. According to Galhiane *et al* [3], another relevant quality of castor oil derivatives is their non-phytotoxicity to many plant species at concentrations that are effective against mites and aphids, which can be very important when using insecticidal soaps. Undecylenic acid, a product of pyrolysis of castor oil serves as source for bactericide, and fungicide [2].

Other uses

Linoleic acid a product of dehydration and undecylenic acid a product of pyrolysis of castor are used for the production of paint, caprylalcohol (octanol) from hydrolysis of the oil is used for production of solvent, plasticizer, antibubbling agent, dehydrator and Turkey red oil from sulphation for softeners [2].

The carboxylic, double bonds and hydroxyl functional groups in castor oil provide reaction sites for the preparation of many useful derivatives which are summarized in Table 1 to 3.

Table 1: Carboxylic functionality reactions

Reactions	**Reactants**	**Products**	**Product applications**
Hydrolysis	Acid	Fatty acid , glycerol	Plasticizer, solvent, dehydrator, floating agent, antibubbling agent [2, 8]
Transesterification	Monohydric alcohols	Esters	Fuel [2, 6]

Alcoholysis	Glycerol, glycols, pentaerythritol, etc.	Glycols, polyols	Urethane polymers [2]
Saponification	Alkalis, metal salts	Soluble, insoluble soaps	Detergents, solvents, plasticizers, plasticizers [2]
Reduction	Sodium	alcohols	Varnishes, lubricants, soaps, paints inks alkyd resin,
Amidation	Alkyl amines, alkanolamines, etc.	Amine salts, amides	Polymers [2]
Halogenation	$SOCl_2$	Fatty Acid halogens	Polymers [2]

Table 2: Double bond

Reactions	**Reactants**	**Products**	**Product applications**
Oxidation	Heat, oxygen, crosslink agent	Polymerized oils	Lubricants [2]
Hydrogenation	Hydrogen (moderate pressure)	Hydroxyl stearates	Resin, polymers, cosmetics, lubricant, paint additives, hair dressing, manufacture of waxes, polishes, carbon paper, candles and crayons [2]
Epoxidation	Hydrogen peroxide	Epoxide oils	Lubricants [2,5,8]
Halogenation	Cl2, Br2, I2	Halogenated oils	Polymers [2]
Addition reaction	S, maleic acid	Polymerized oils	Polymers [5]
Sulphation	Conc. H2SO4	Turkey red oil	Detergents, lubricants, softeners, and dyes [2, 5]

Table 3: Hydroxyl functionality

Reactions	**Reactants**	**Products**	**Product applications**
Dehydration	Acid Catalyst (heat)	Dehydrated oils, Linoleic acid	protective coating, vanishes, lubricants, soaps, paints, inks, manufacture of alkyd resins, coatings, appliance finishes and primers [2]
Hydrolysis	NaOH	Linoleic acid, capryl (octanol) alcohol	Plasticizer,solvent, dehydrater, floating agent, antibubbling agent [2,8]
Pyrolysis	Heat	Undecylenic acid, heptaldehyde [2]	Perfumery, pharmaceutical, polymeric formulations, insecticide and bactericide and fungicide [2]
Halogenation	PCl5, POCl3	Halogenated castor oils	Polymers [2]
Esterification	Acetic-, phosphoric-, maleic-, phthalic anhydrides	Alkyl and alkylaryl esters, phosphate esters	Biofuels [2, 8]
Alkoxylation	Ethylene and/or propylene oxide	Alkoxylated castor oils [8]	plasticizers, textiles, cosmetics [8]
Sulphation	Conc. H_2SO_4	Turkey red oils	Detergents, lubricants, softeners, and dyes [2]

Urethane reactions	Isocyanates	Urethane polymers	biomedical implants, coatings, cast elastomers, thermoplastic elastomers, rigid foams, semi-rigid foams, sealants, adhesives and flexible Foams [6]

CONCLUSION

Castor oil can be extracted by cold pressing, soxhlet and mechanical methods depending on end use for chemical processing. Its oil yield depends on the geographical location and the method of extraction applied. It is environmentally friendly, renewable and sustainable. Castor oil with three functional groups, undergoes hydration, hydrolysis, hydrogenation, Epoxidation, halogenation, amidation, sulphation, esterification, transesterification, pyrolysis etc. transformations yielding different products that can replace the use of petroleum products. From castor oil products for pharmaceuticals, cosmetics, insecticides, pesticides, fungicides, bactericide, polymers, solvents and many other chemical industrial materials are produced. Exploring castor oil will lead to development of small, medium and even large scale industries. Increase in the production of castor oil will reduce the dependency on non-degradable petroleum based products. Castor oil based polymers have the following advantages over those from fossil monomers; cheaper, renewable, sustainable and biodegradable [2]. Large scale engagement of castor plantation will reduce unemployment in Nigeria by 50% Olewale [18]

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